

APPENDIX B

SUBSURFACE SOIL CONCEPTUAL MODEL

This white paper provides the technical basis for development of an equation that computes a risk-based subsurface soil radionuclide concentration using a risk-based surface soil radionuclide concentration and other model parameters. The model is based on potential human exposure to subsurface soil that is brought to the surface by a burrowing animal.

HUMAN EXPOSURE PATHWAY MECHANISM TO SUBSURFACE SOIL

A primary mechanism by which a human could be exposed in the future to subsurface soil at RFETS is through contact with subsurface soil that has been brought to the surface by burrowing animals, i.e., prairie dogs. The subsurface soil would occur at the surface in small isolated areas surrounding the burrows (the prairie dog mound). In effect, the prairie dog mound represents a localized area of soil with radionuclide activities potentially higher than the surrounding soils, i.e., a hot spot. This mechanism forms the basis for the equation that is used to evaluate the risk posed by radionuclides in the subsurface soil.

DEVELOPMENT OF THE SUBSURFACE SOIL EQUATION

This section presents prairie dog colony model parameters, model assumptions, and development of the equation that computes the risk-based subsurface soil radionuclide concentration.

Selected Parameters and Assumptions for a Prairie Dog Colony Model

White and Carlson (1984) evaluated the effects of the black-tailed prairie dog activity on soil mixing. These prairie dogs occupy short- and mixed-grass prairies in a belt that runs north-south along the eastern side of the Rocky Mountain range, and are thus relevant to RFETS. The key parameters that were used in their study and that are applicable to development of a prairie dog colony model are as follows:

- ◆ There are 62 burrows per hectare (6.2 burrows per 1000 m²).
- ◆ The average mound diameter is 0.6 m (area = 0.28 m²).

Three conservative assumptions have also been used for the prairie dog colony model:

- ◆ The area disturbed by the prairie dog in the subsurface is equal to the average area surrounding a burrow (1000 m²/6.2 burrows = 160 m² per burrow).
- ◆ All of the subsurface soil brought to the surface comes from the depth where contaminated subsurface soil is encountered. The dilution of the subsurface soil with clean subsurface soil that is removed at more shallow (or deeper depths) has been ignored to provide a wide margin of error to accommodate the uncertainties in this analysis.
- ◆ The entire area of subsurface radionuclide contamination at the Site is overlain by prairie dog colonies. This is a very conservative assumption.

Equation Development

The equation that relates a risk-based subsurface soil radionuclide concentration (CONC_{subs}) to a risk-based surface soil radionuclide concentration (CONC_{surf}) is derived from the following considerations:

1. human exposure to the small area of subsurface soil that is brought the surface (the “hot spot”) is a fraction of the exposure to the surrounding surface soil [application of an Area Factor (AF)], and
2. the possibility exists that, at the depth where contamination is found, the area of contamination may be less than the area disturbed by the prairie dog, i.e., the subsurface soil

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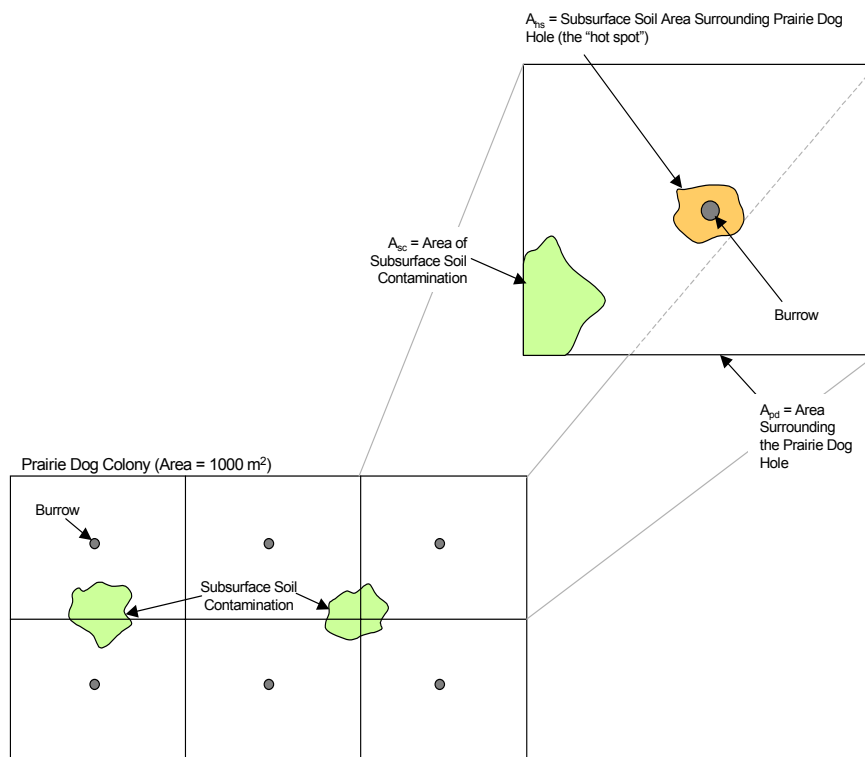
that is brought to the surface from a specific depth is a mixture of contaminated and non-contaminated soil from that depth [application of a Dilution Factor (DF)].

Given the above considerations, the equation is as follows:

$$\text{CONC}_{\text{subs}} = \text{CONC}_{\text{surf}} \times \text{AF} \times \text{DF} \quad (\text{Equation 1})$$

where AF is a function of the prairie dog mound area, i.e., the “hot spot” (A_{hs}), and DF is a function of the total area disturbed by the prairie dog (A_{pd}) and the area of subsurface contamination within this disturbed area (A_{sc}). The area terms are defined in Figure 1.

Figure 1 Terminology for Calculation of the Risk-Based Subsurface Soil Radionuclide Concentration



AF is established per DOE guidance (DOE 2002)¹. This guidance provides a method for determining if soil hot spots with radionuclide activities significantly higher than the authorized release limit are protective of individuals. For this application, the authorized limit is $\text{CONC}_{\text{surf}}$.

In the guidance, AF is applied as follows:

$$C_{\text{hs}} = \text{CONC}_{\text{surf}} \times \text{AF} \quad (\text{Equation 2})$$

¹ The guide provides assistance in determining the disposition of property under the requirements of DOE 5400.5, Radiation Protection of the Public and Environment, and its proposed successor, 10 CFR 834, "Radiation Protection of the Public and the Environment. The Area Factor (AF) is based on authorized release limits derived from a 25 mrem/yr dose, and ensures that unlikely exposure to the hot spot would not cause this primary dose to be exceeded. AF further assumes the hot spot areas are equal to or less than 25 m², and 100 m² is the averaging area for compliance with the authorized limit.

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where C_{hs} is the maximum allowable hot spot concentration.

AFs are a function of the area of the hot spot (A_{hs}) and the DOE guidance provides a table (Table 1 in DOE (2002)) for selection of an AF for a given A_{hs} . Application of the table and guidance indicates that AF is 30 for a hot spot with an area of 0.28 m^2 (A_{hs}), i.e., the prairie dog mound area².

Since $DF = A_{pd}/A_{sc} = 160/A_{sc}$, substituting this term and AF equal to 30 into Equation 1 gives

$$\text{CONC}_{\text{subs}} = 4800 \times \text{CONC}_{\text{surf}}/A_{\text{sc}} \quad (\text{Equation 3})$$

Where A_{sc} is in square meters.

Equation 3 is the equation that relates the $\text{CONC}_{\text{subs}}$ to $\text{CONC}_{\text{surf}}$ and the area of subsurface contamination (A_{sc}). In effect, a factor is applied to the $\text{CONC}_{\text{surf}}$ to arrive at the $\text{CONC}_{\text{subs}}$ for a given area of subsurface soil contamination. The resulting factors are shown in tabular form in Table 2.

Table 2 – Factors Applied to $\text{CONC}_{\text{surf}}$ to Compute $\text{CONC}_{\text{subs}}$

$A_{sc} (\text{m}^2)$	Factor
24	200
48	100
80	60

As can be seen, as the area of contamination increases, the factor decreases. The factor range of 60 to 200 and the associated areas are proposed for identifying subsurface soil radionuclide concentrations that will trigger an evaluation and an accelerated action determination.

REFERENCES

White, E. M., and D. C. Carlson. 1984. Estimating Soil Mixing by Rodents. Proceedings of the South Dakota Academy of Sciences 63:34-37.

DOE 2002. Draft Implementation Guide, Control and Release of Property with Residual Radioactive Material for use with DOE 5400.5, Radiation Protection of the Public and Environment. U.S. Department of Energy.

² The DOE guidance table notes that hot spot areas less than 1 m^2 are to be averaged over a 1 m^2 area, and the average shall not exceed 10 times the authorized limit (AL) for the property. [The notation in this paper has been changed from AL to CONC to avoid confusion with RFCA action levels.] As noted previously, the prairie dog mound ("hot spot") has an area of 0.28 m^2 (A_{hs}). Because this area is smaller than 1 m^2 , the average radionuclide concentration in surface soil over a 1 m^2 area can not exceed 10 times $\text{CONC}_{\text{surf}}$. Calculation of this average and equating it to 10 times the $\text{CONC}_{\text{surf}}$ is shown below.

$$\text{Average Radionuclide Concentration over } 1 \text{ m}^2 = \text{CONC}_{\text{surf}} \times 10 = A_{hs} * C_{hs} + (1 - A_{hs}) * C_s$$

Where C_s is the radionuclide concentration surrounding the hot spot.

Given $A_{hs} = 0.28 \text{ m}^2$ and assuming that C_s is zero (i.e. significantly below C_{hs}), C_{hs} calculates to be $\text{CONC}_{\text{surf}} \times 36$, i.e., AF is 36 (see Equation 2). However, DOE Order 5400.5 requires reasonable efforts to be made to remove any radionuclide source that exceeds 30 times the appropriate limit. This effectively limits AF to 30.